

Real-Time Monitoring Using Phasor Technology

Eastern Interconnection Phasor Project

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by

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Outline

- Application of Phasor Technology for Real-Time Monitoring
 - Operational Value

- Synchronized Phasor Wide Area Network and Architecture

- Grid-3P™: Real-Time Monitoring using Phasor Measurements
 - Wide Area Visualization
 - Local Area Visualization

- Conclusion

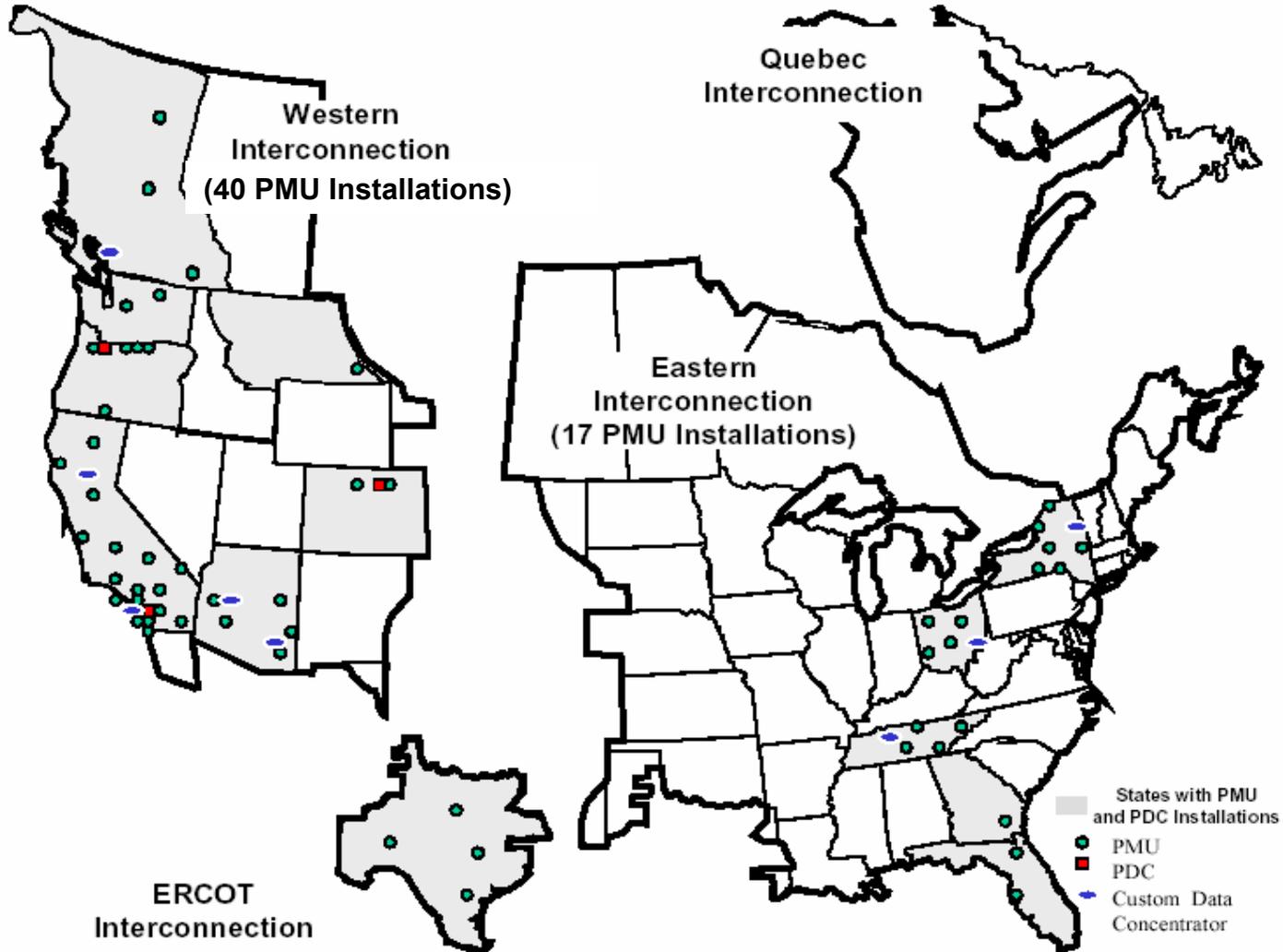
Phasor Technology Applications

- Real-Time Monitoring Applications for Use by Dispatchers
 - Display of Phase Angles and Voltages in Real-Time
 - Not Currently Available
 - Display of Frequency, Frequency Response, Load/Resource Imbalance at finer resolution than SCADA
 - Alarming Based on Phasors
 - Novel Approach/More Accurate

- Dynamic Stability Assessment in Real-Time

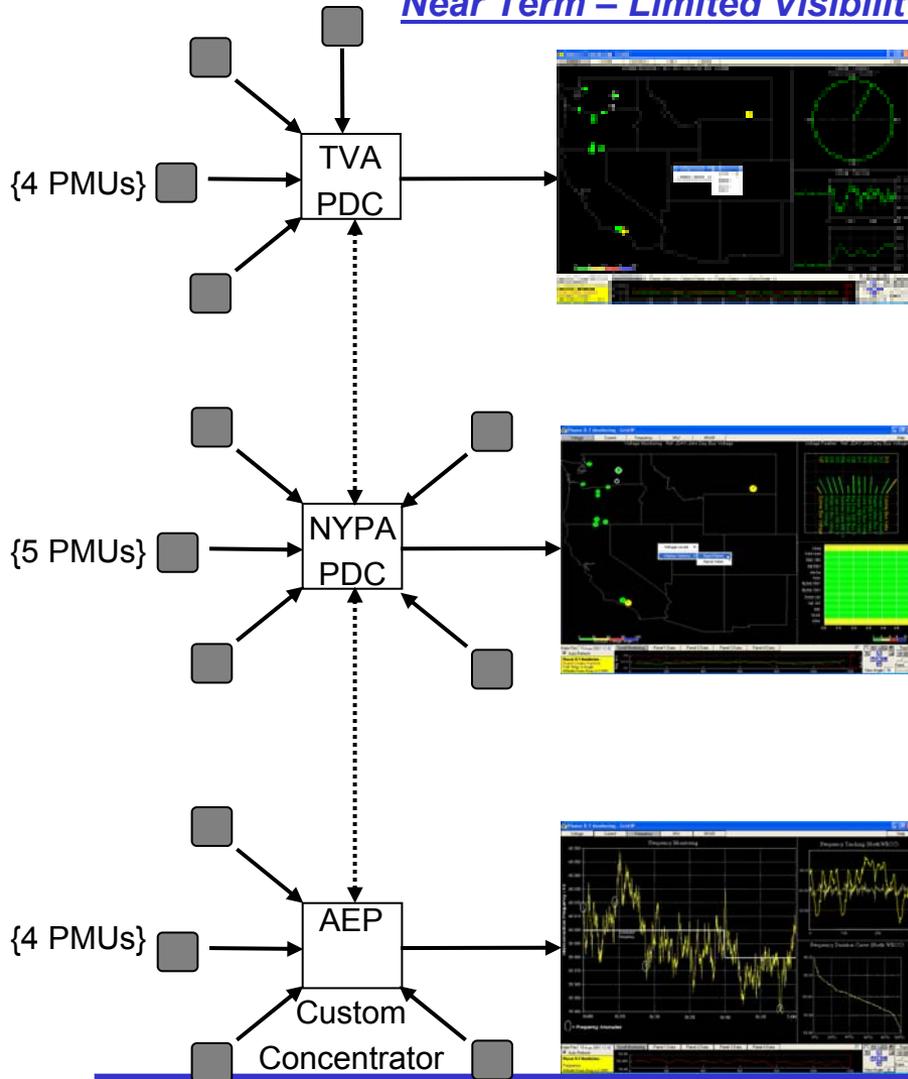
- Improved State Estimation using Phasor Measurements

Synchronized Phasor Wide Area Network

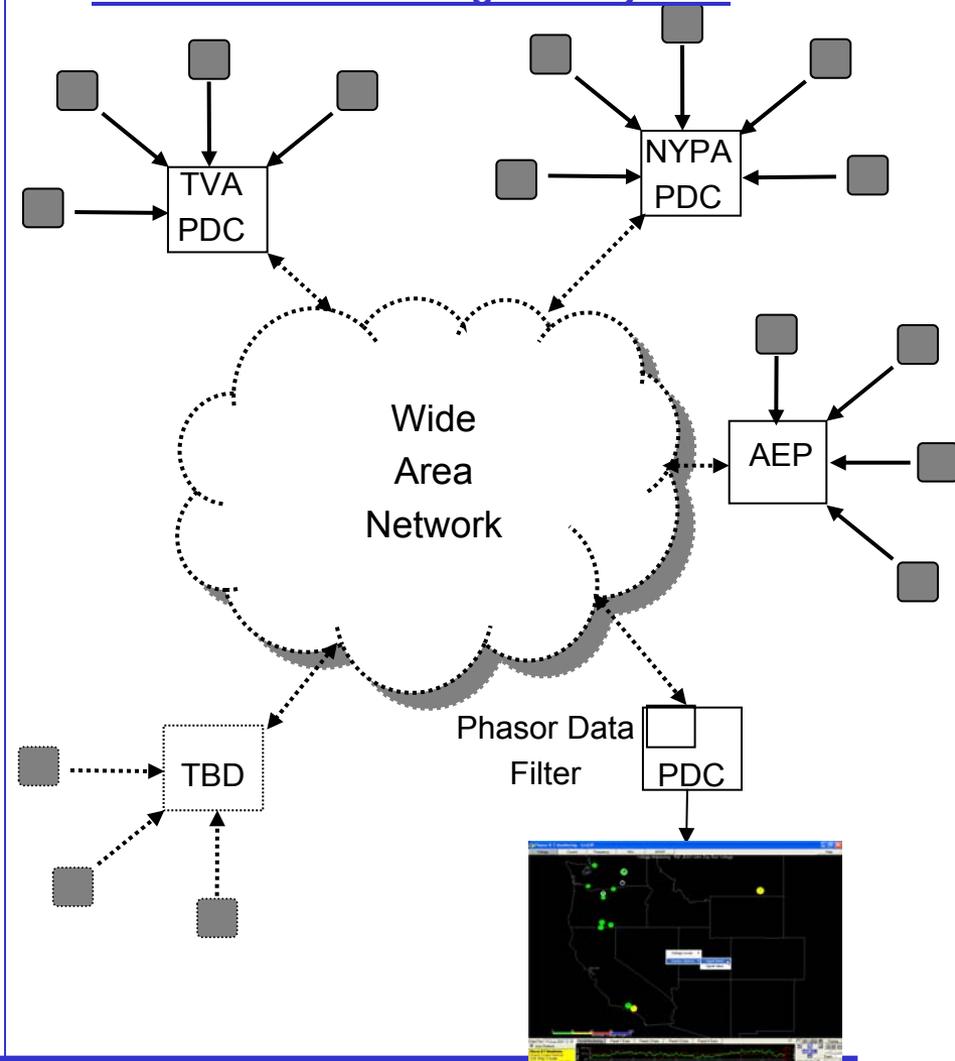


Phasor Application with Current and Future Eastern Interconnection Network

Near Term – Limited Visibility



Future Planned – Integrated System



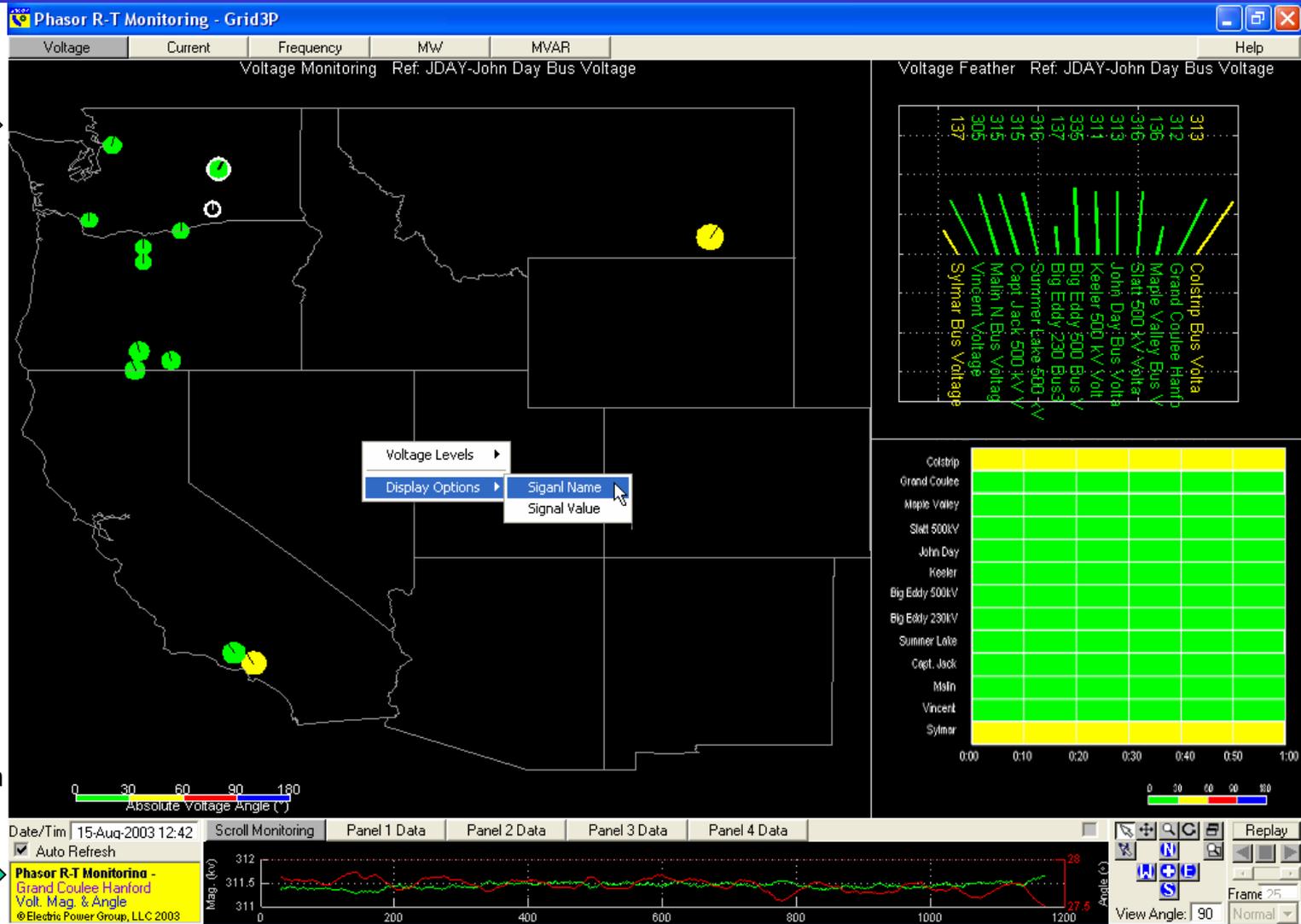
Real-Time Phasor Application

Wide Area Monitoring of Voltages/Phase Angles

Reference:
- Transparent
- Selectable

Phasor by:
- Diameter
- Needle
- Color
- Value

Tracking:
- Plot
- Tabular Form



Sorted by
Phasor
Differences



Real-Time Phasor Application

Local Area Monitoring at Selected Locations

Monitoring

- Wide Area/Local Area

- Angle Differences

- Decreasing Voltage Magnitudes

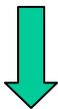


Alarming

Thresholds based on:

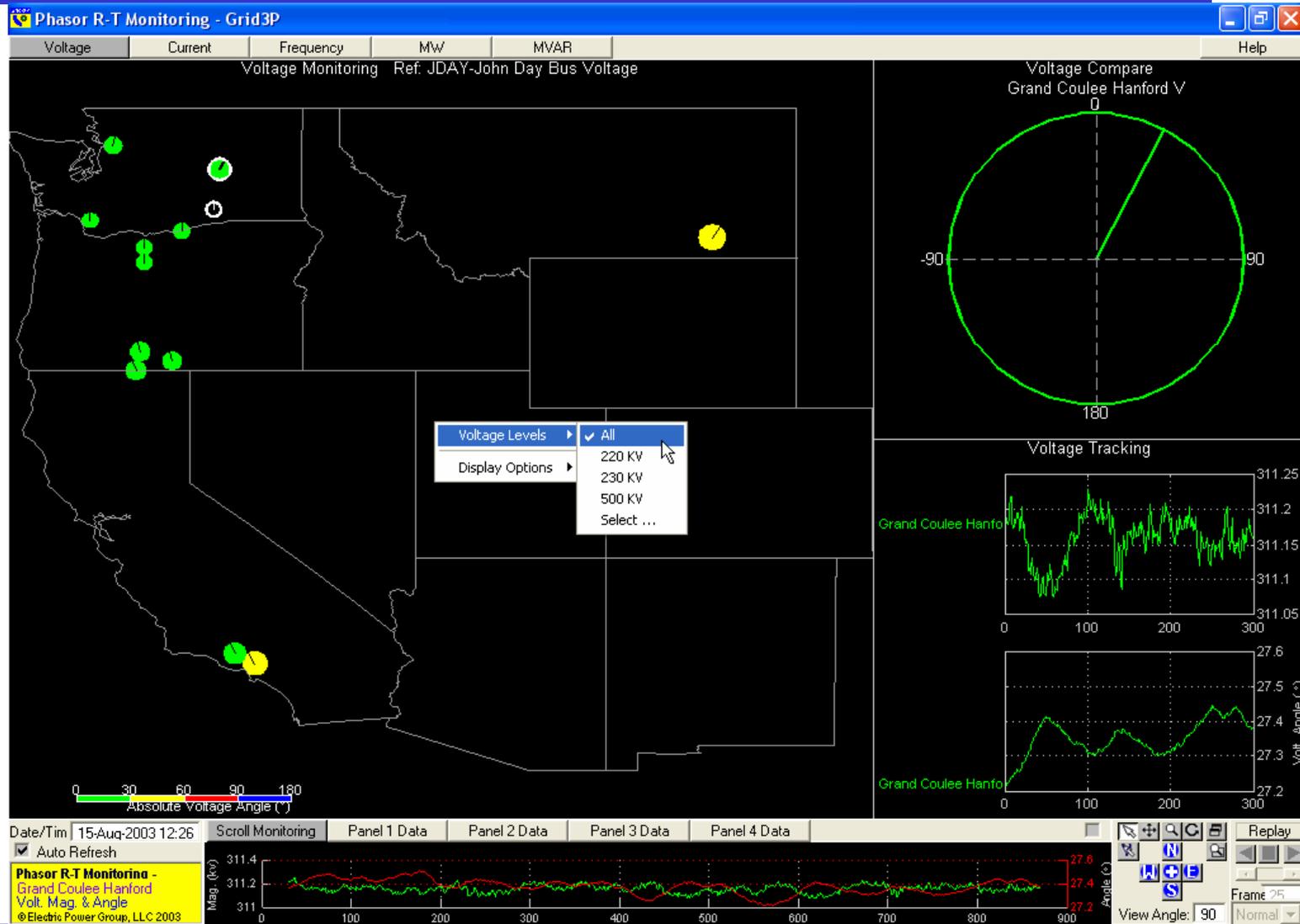
- Detrimental Phase Angle Differences

- Voltage Magnitudes



Action

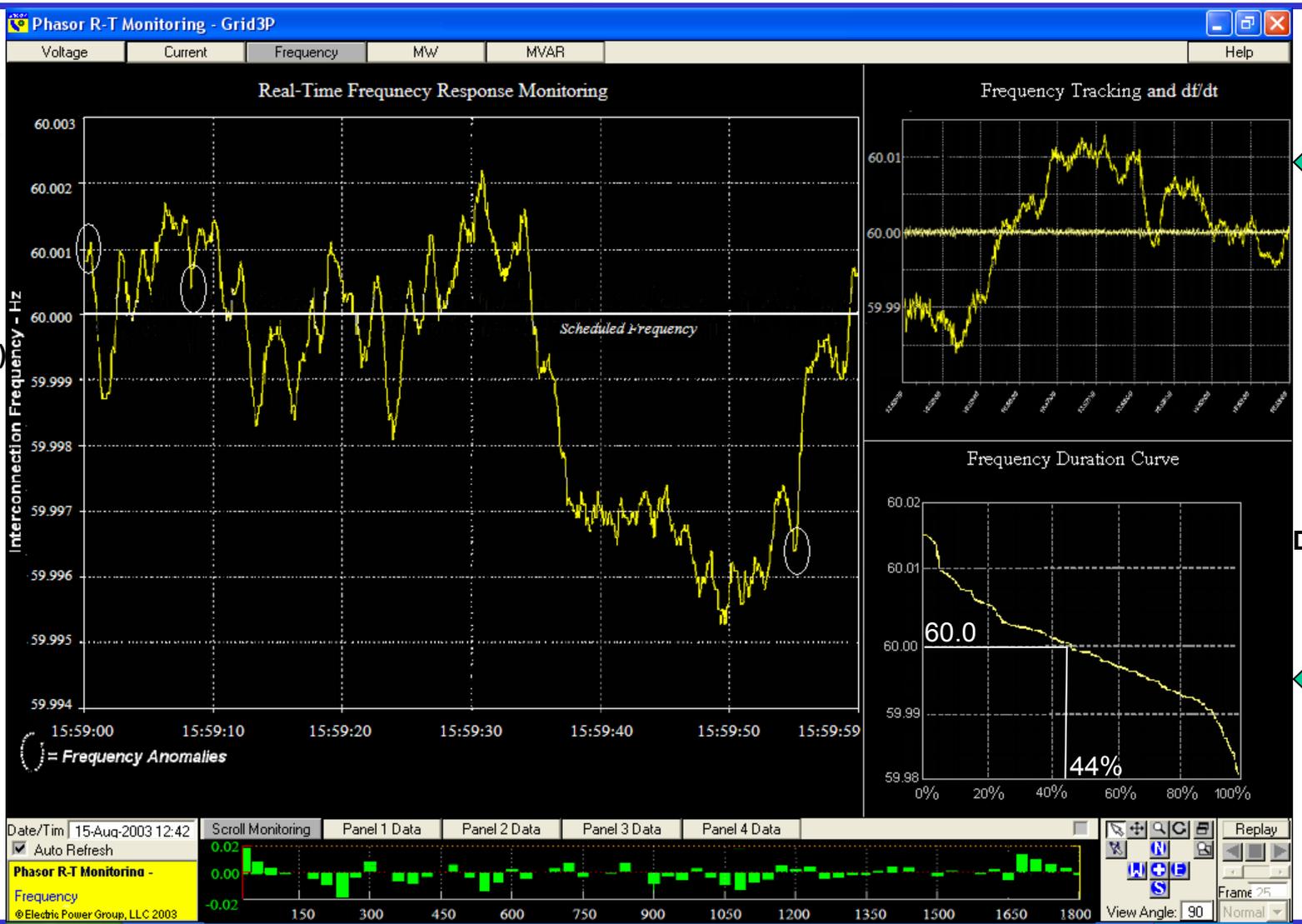
- Notifications



Real-Time Monitoring of Interconnection Frequency/Frequency Response

Anomalies
 Frequency Acceleration / Deceleration (Hz) + Load / Resource Imbalance (MW)

Tracking Δf



5 Min. Freq. df/dt

Duration Curve



Conclusion

- Improve System Visibility
- Improve Monitoring Capability
- Provide Dispatchers and Operational Personnel with Applications in Phasor Technology (besides Post-Disturbance Analysis)
- Improve Wide Area and Local Visualization Solutions for Real-Time Monitoring
- Monitor Real-Time System Operation within Predefined Limits
- Next Step: Solicit Participation for Beta Testing of Displays



Questions ?



Real-Time Stability Monitoring Methodology

Voltage Phasor

Identify Key Transfer Points

Determine Angle Thresholds in Terms of Angle Differences using Off-line Stability Assessment Software¹

Utilize Grid-3P Software to Monitor / Alarm Phasor Differences w.r.t. Corresponding Thresholds

Specify Absolute Voltage Magnitude Thresholds

Utilize Grid-3P Software to Monitor / Alarm Voltage Magnitudes w.r.t. Corresponding Thresholds

Frequency

Determine Interconnection Frequency

Specify Frequency Limits in Terms of Frequency Change / Power Imbalance

Utilize Grid-3P Software to Monitor / Alarm Frequency Deviations w.r.t. Corresponding Thresholds

Power Flow

Identify Key Power Path Flows (e.g. COI)

Specify Path Flow Limits

Utilize Grid-3P Software to Monitor / Alarm Path Flows w.r.t. Corresponding Thresholds

¹ Technique may be applied to monitor thresholds for internal generator phase angles.

Grid3P - Phasor Real Time Monitoring

Application Matrix

	R-T Monitoring Panel	Tracking Panel	Prediction Panel	Action Panel	Alarming
Voltage (Wide)	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> -All PMU Locations - Angle & Mag. - Dial Graphic - 1 Sec. Res. (Ave.)	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> -All PMUs - Angle & Mag. - Feather Plot Sorted by Decreasing Angle - 1 Sec. Res. (Ave.)	<u>Refresh Rate:</u> 10 Sec. <u>Display:</u> - All PMUs - Angle. Vs. Time - Mesh Plot - 10 Sec. Res. (Ave.)	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Selected PMU - Angle Vs. Time Plot - Mag. Vs. Time Plot - 1/30 Sec. Res. - 1 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Method:</u> Violation of Any: - Angle Diff. Thresholds - Mag. Threshold - 1/30 Sec. Res.
Voltage (Local)	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> -All PMU Locations - Angle & Mag. - Dial Graphic - 1 Sec. Res. (Ave.)	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Phasor Angle - Up to Six PMUs - Polar Plot - 1 Sec. Res. (Ave.)	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Selected PMU - Angle Vs. Time Plot - Mag. Vs. Time Plot - 1 Sec. Res. (Ave.) - 5 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Selected PMU - Angle Vs. Time Plot - Mag. Vs. Time Plot - 1/30 Sec. Res. - 1 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Method:</u> Violation of Any: - Angle Diff. Thresholds - Mag. Threshold - 1/30 Sec. Res.
Freq.	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Interconnection Freq. - Freq. Vs Time Plot - df/dt Vs Time Plot - 1/30 Sec. Res. (Ave.) - 1 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Freq. Vs Time Plot - df/dt Vs Time Plot - 1 Sec. Res. (Ave.) - 5 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Freq. Duration Curve - 5 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Freq. Vs Time Bar Plot - 1 Sec. Res. - 1 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Method:</u> Violation of Any: - df/dt Threshold - 1/30 Sec. Res.
MW MVAR	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Directional Path Flows - Bar Graphs - 1 Sec. Res. (Ave.)	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Selected Path Flow - Flow Vs Time Plot - 1 Sec. Res. (Ave.) - 5 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Selected Path Flow - Flow Duration Curve - 5 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Display:</u> - Selected Path Flow - Flow Vs Time Bar Plot - 1 Min. Res. - 60 Min. Duration	<u>Refresh Rate:</u> 1 Sec. <u>Method:</u> Violation of Any: - Path Flow Thresholds - 1/30 Sec. Res.

